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Shirata

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(54) **LUBRICANT SENSOR**

(56) **References Cited**

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U.S. PATENT DOCUMENTS

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2,580,500 A * 1/1952 Albert 356/442
3,692,410 A * 9/1972 Jurany et al. 356/40
4,040,743 A * 8/1977 Villaume et al. 356/73
4,114,038 A * 9/1978 Parker 250/239

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(Continued)

FOREIGN PATENT DOCUMENTS

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JP S53-124988 U 10/1978
JP 60-224043 A 11/1985

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(Continued)

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OTHER PUBLICATIONS

§ 371 (c)(1),
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International Search Report; PCT/JP2011/077980; Mar. 6, 2012.
(Continued)

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(57) **ABSTRACT**

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(58) **Field of Classification Search**

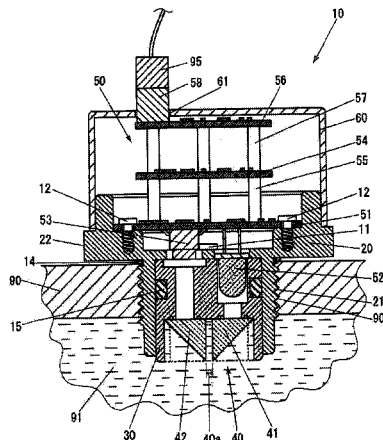
CPC G01N 33/28

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See application file for complete search history.

A speed reducer for an industrial robot includes a speed reducer main body and a lubricant deterioration sensor for detecting deterioration of a lubricant in the speed reducer main body. The lubricant deterioration sensor includes a light emitting element for emitting light, a color light receiving element for detecting a color of received light, a clearance forming member forming an oil clearance in which the lubricant enters, and a support member supporting the light emitting element, the color light receiving element, and the clearance forming member. The clearance forming member is transmissive so that the light emitted from the light emitting element transmits therethrough. The oil clearance is provided on an optical path from the light emitting element to the color light receiving element.

6 Claims, 11 Drawing Sheets



(56)

References Cited**U.S. PATENT DOCUMENTS**

4,171,909	A *	10/1979	Kramer et al.	356/73
4,534,651	A *	8/1985	Minikane	356/440
4,851,665	A *	7/1989	Pesavento et al.	356/412
5,001,938	A *	3/1991	Downie	73/864.34
5,007,740	A *	4/1991	Jeannotte et al.	356/436
5,069,524	A	12/1991	Watanabe et al.	
5,121,110	A	6/1992	Mahar, Jr. et al.	
5,181,082	A *	1/1993	Jeannotte et al.	356/436
5,194,910	A *	3/1993	Kirkpatrick, Jr. et al.	356/70
5,208,465	A	5/1993	Jacobson	
5,293,107	A	3/1994	Akeel	
5,371,600	A *	12/1994	Hsia et al.	356/436
5,402,241	A *	3/1995	Jeannotte et al.	356/436
5,404,217	A *	4/1995	Janik et al.	356/246
5,530,553	A *	6/1996	Hsia et al.	356/436
5,567,306	A	10/1996	DeWachter	
5,729,006	A *	3/1998	Maeda	250/231.13
6,546,814	B1	4/2003	Choe et al.	
7,027,160	B2 *	4/2006	Sperling	356/446
7,339,657	B2	3/2008	Coates	
7,612,874	B2 *	11/2009	Kong et al.	356/70
7,916,299	B2 *	3/2011	Trump et al.	356/440
8,155,891	B2 *	4/2012	Kong et al.	702/25
8,379,192	B2 *	2/2013	Mannhardt et al.	356/73
8,493,561	B2 *	7/2013	Park et al.	356/326
8,542,363	B2 *	9/2013	Wynn et al.	356/440
8,648,321	B2 *	2/2014	Schenkel et al.	250/573
2002/0005954	A1 *	1/2002	Sperling	356/446
2002/0162407	A1	11/2002	Nightlinger et al.	
2003/0142316	A1 *	7/2003	Schenkl et al.	356/442
2004/0233431	A1	11/2004	Ganz et al.	
2005/0066707	A1	3/2005	Katsuki et al.	
2007/0046936	A1	3/2007	Mauzy et al.	
2008/0024761	A1 *	1/2008	Kong et al.	356/70
2009/0036250	A1	2/2009	Koyama et al.	
2009/0086212	A1	4/2009	Kitamura	
2009/0140754	A1 *	6/2009	Schenkl et al.	324/693
2009/0216464	A1 *	8/2009	Kong et al.	702/25
2009/0228239	A1	9/2009	Inoue et al.	
2009/0279072	A1 *	11/2009	Arakawa	356/70
2010/0027015	A1 *	2/2010	Schweng et al.	356/437
2010/0157304	A1 *	6/2010	Takahashi et al.	356/442
2012/0038925	A1 *	2/2012	Gahr et al.	356/440
2012/0162650	A1 *	6/2012	Wynn et al.	356/432
2012/0162652	A1 *	6/2012	Schenkl et al.	356/436
2013/0250281	A1	9/2013	Shirata	
2013/0250303	A1 *	9/2013	Shirata et al.	356/436
2014/0146307	A1 *	5/2014	Arrondo et al.	356/70

FOREIGN PATENT DOCUMENTS

JP	63-184040	A	7/1988
JP	H01-501247	A	4/1989

JP	01-119741	A	5/1989
JP	06-182649	A	7/1994
JP	07-118778	A	5/1995
JP	07-146233	A	6/1995
JP	08-086751	A	4/1996
JP	08-126369	A	5/1996
JP	10-104160	A	4/1998
JP	H11-271217	A	10/1999
JP	2000-146696	A	5/2000
JP	2001-242079	A	9/2001
JP	2002-006039	A	1/2002
JP	2007-198767	A	8/2007
JP	2007-278903	A	10/2007
JP	2009-226488	A	10/2009
JP	4523977	B2	8/2010
JP	2012-143837	A	8/2012
WO	88/02109	A1	3/1988
WO	99/49302	A1	9/1999
WO	2007/091568	A1	8/2007

OTHER PUBLICATIONS

International Search Report; PCT/JP2011/077977; Mar. 6, 2012.

The Final Office Action issued by the U.S. Patent Office on Apr. 24, 2014, which is related to U.S. Appl. No. 13/991,132.

Non-Final Office Action issued by the U.S. Patent Office on Aug. 15, 2014, which is related to U.S. Appl. No. 13/991,132.

An Office Action; "Notification of Reasons for Refusal," issued by the Japanese Patent Office on Nov. 6, 2014, which corresponds to Japanese Patent Application No. 2010-269097 and is related to U.S. Appl. No. 13/991,133; with English language translation.

An Office Action; "Notification of Reasons for Refusal," issued by the Japanese Patent Office on Nov. 18, 2014, which corresponds to Japanese Patent Application No. 2011-003853 and is related to U.S. Appl. No. 13/991,133; with English language translation.

The final Office Action issued by the U.S. Patent Office on Jan. 18, 2015, which corresponds to U.S. Appl. No. 13/991,132 and is related to U.S. Appl. No. 13/991,133.

The non-final Office Action issued by the U.S. Patent Office on May 22, 2015, which corresponds to U.S. Appl. No. 13/991,132 and is related to U.S. Appl. No. 13/991,133.

An Office Action; "Final Rejection," issued by the Japanese Patent Office on Jul. 1, 2015, which corresponds to Japanese Patent Application No. 2010-269097 and is related to U.S. Appl. No. 13/991,132; with English language translation.

An Office Action; "Final Rejection," issued by the Japanese Patent Office on Jun. 17, 2015, which corresponds to Japanese Patent Application No. 2011-003853 and is related to U.S. Appl. No. 13/991,132; with English language translation.

* cited by examiner

Fig. 1

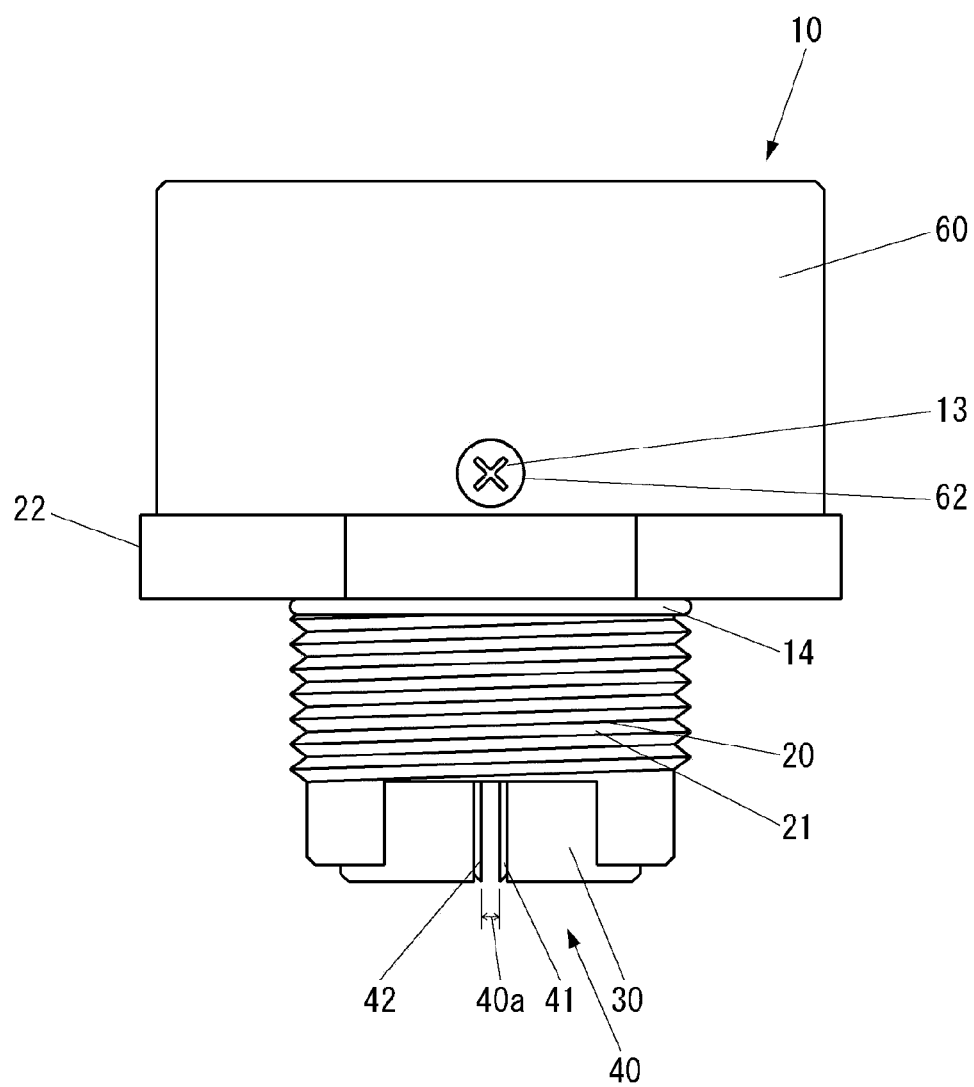


Fig. 2

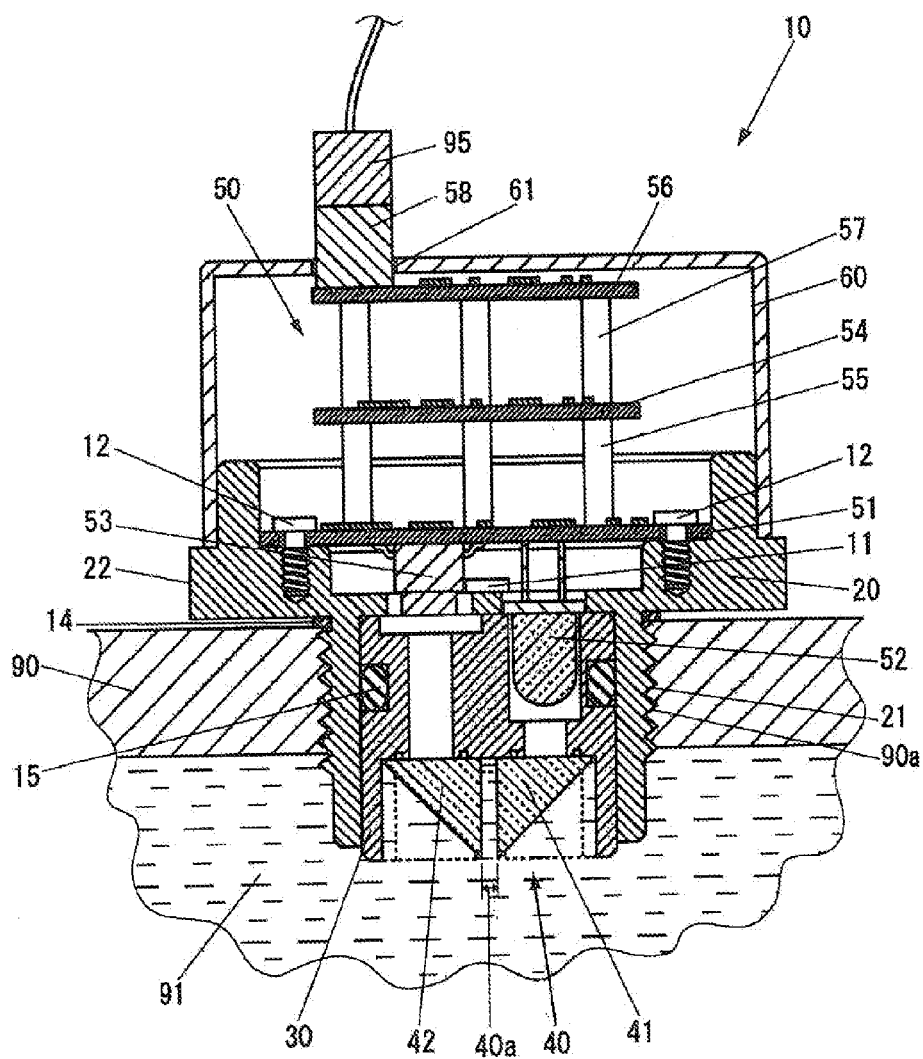


Fig. 3A

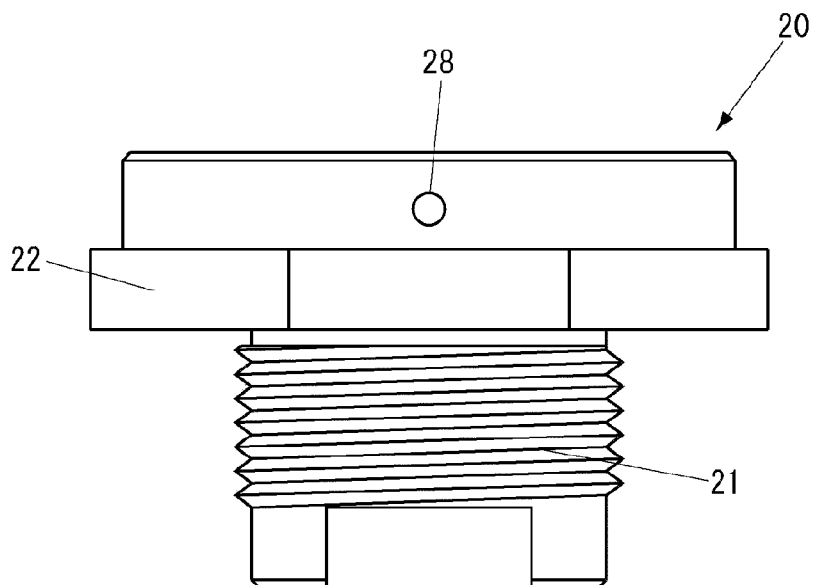


Fig. 3B

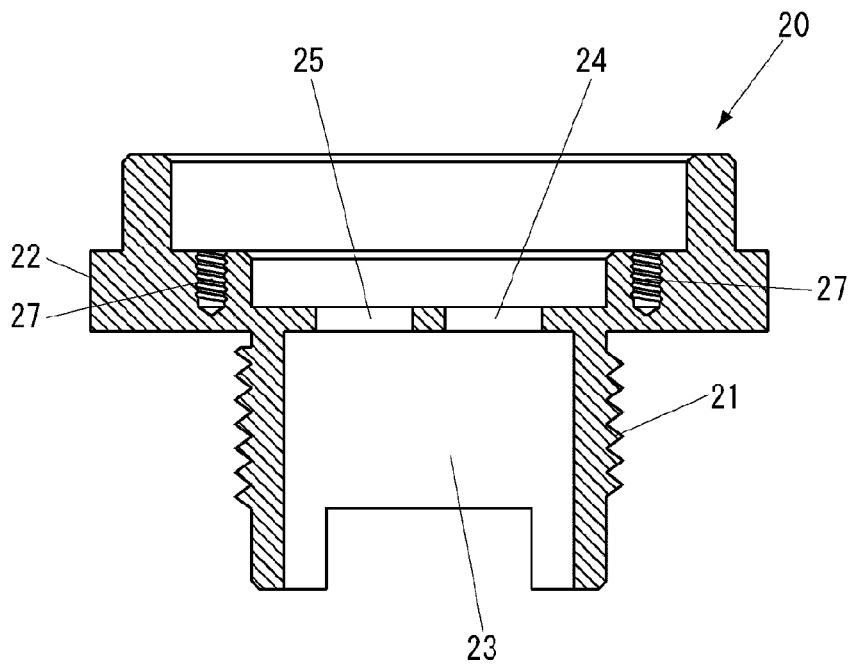


Fig. 4A

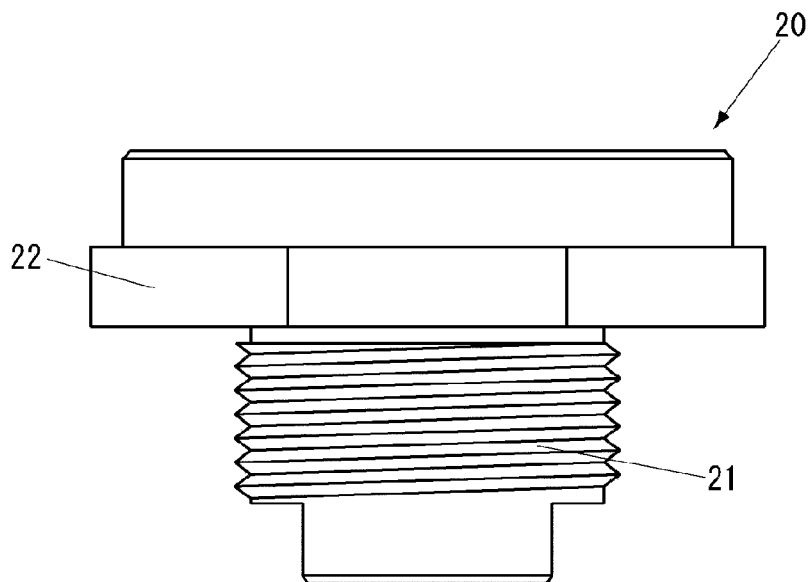


Fig. 4B

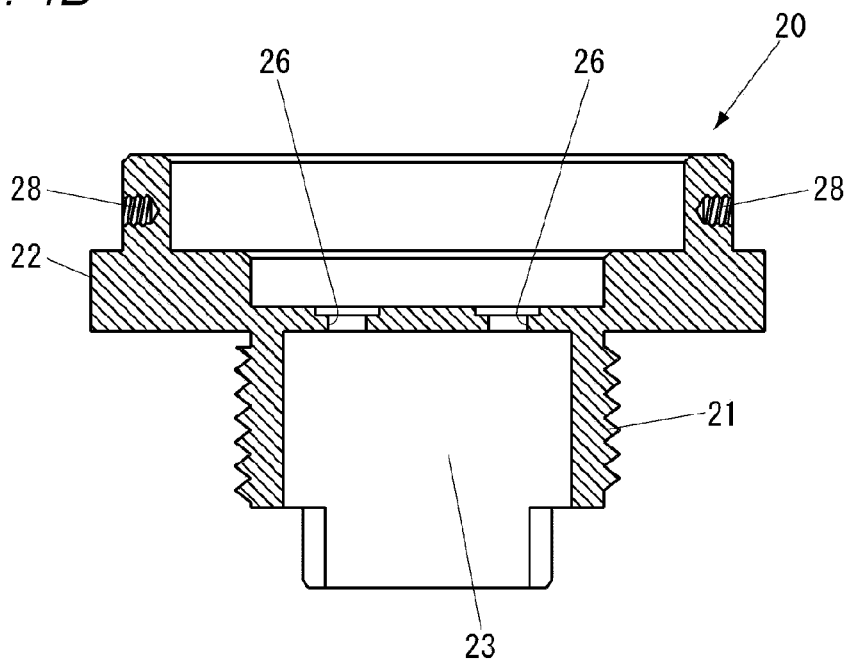


Fig. 5A

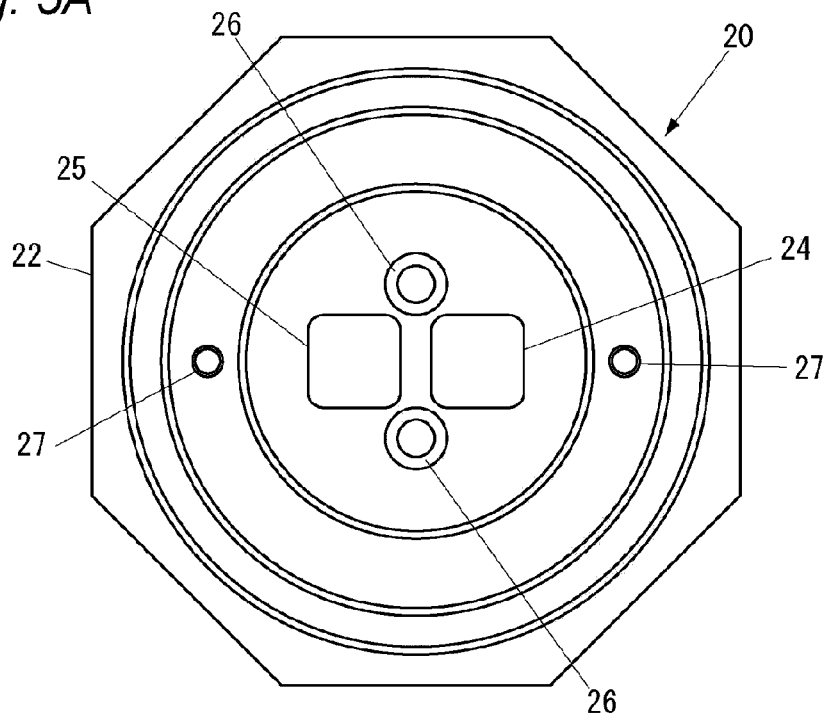
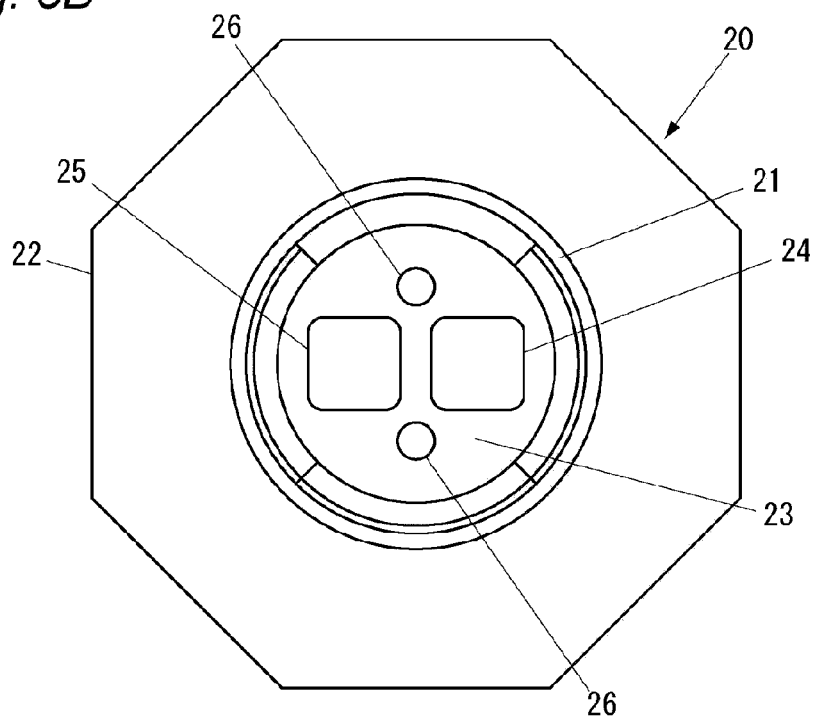


Fig. 5B



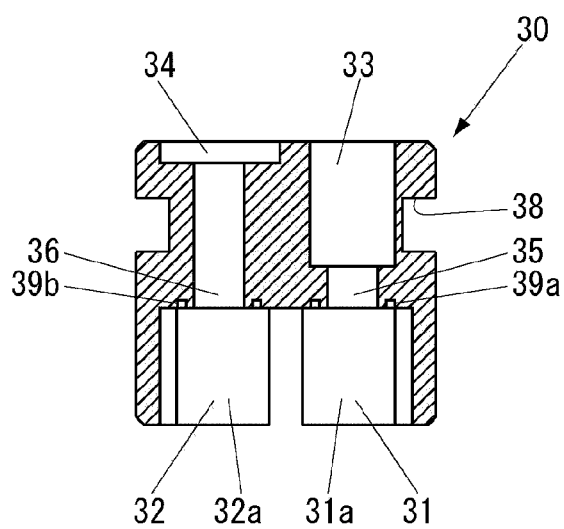


Fig. 7A

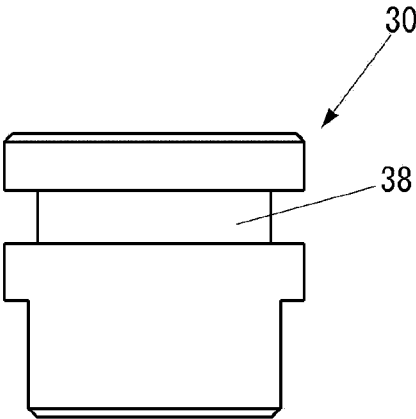


Fig. 7B

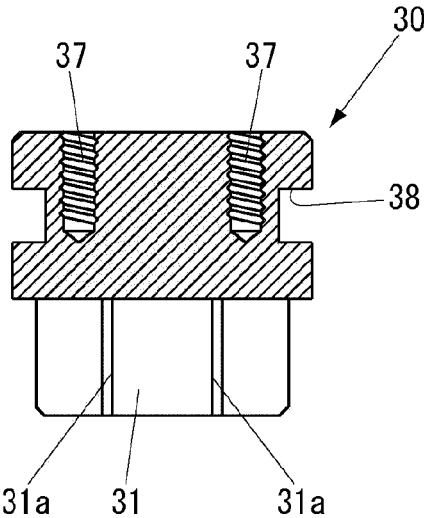


Fig. 8A

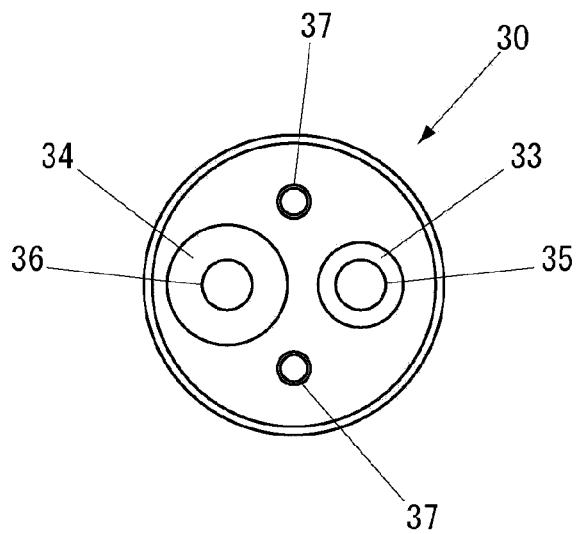


Fig. 8B

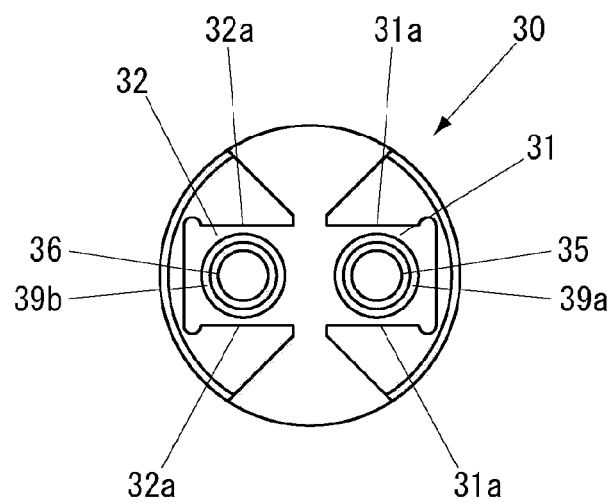


Fig. 9

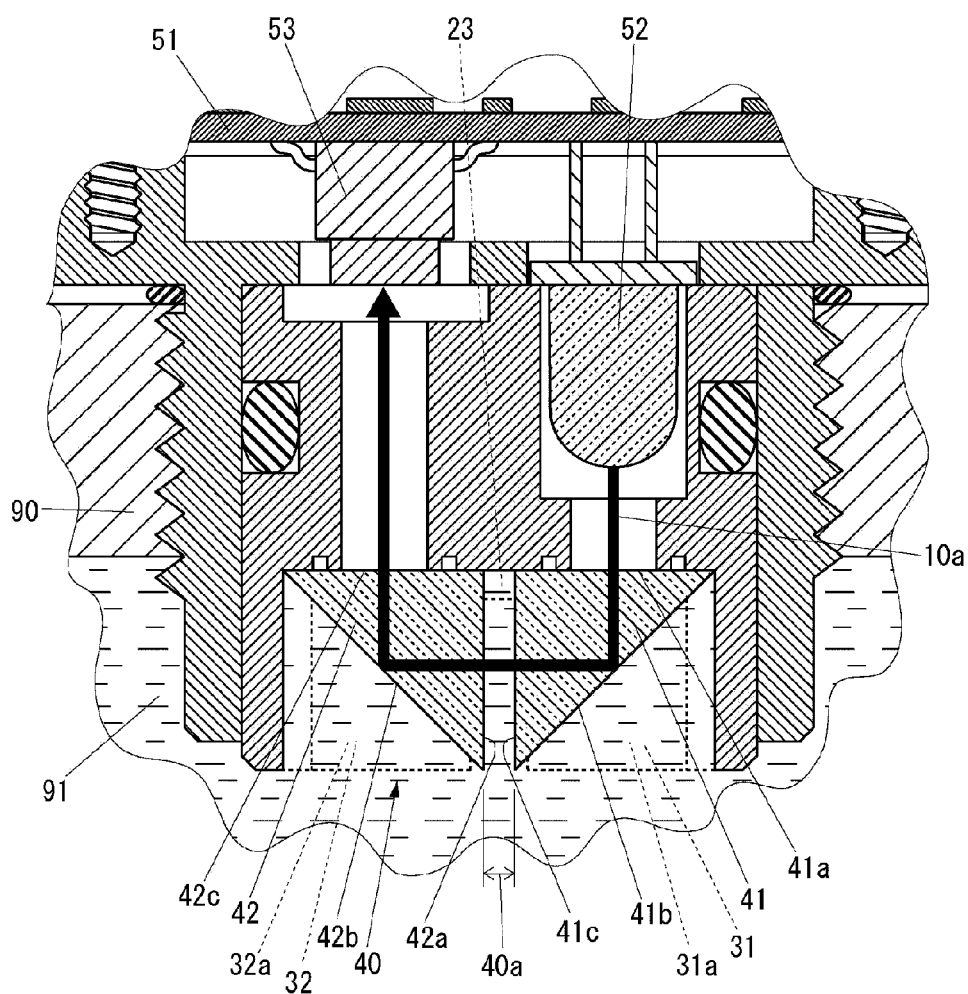


Fig. 10A

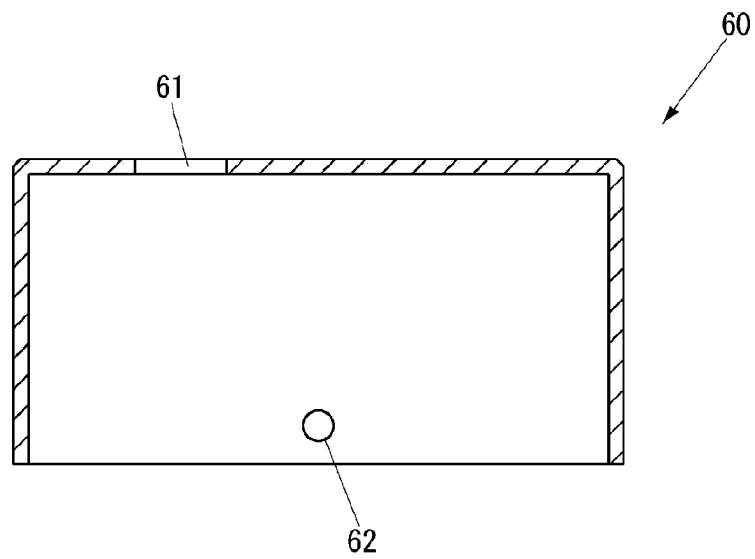


Fig. 10B

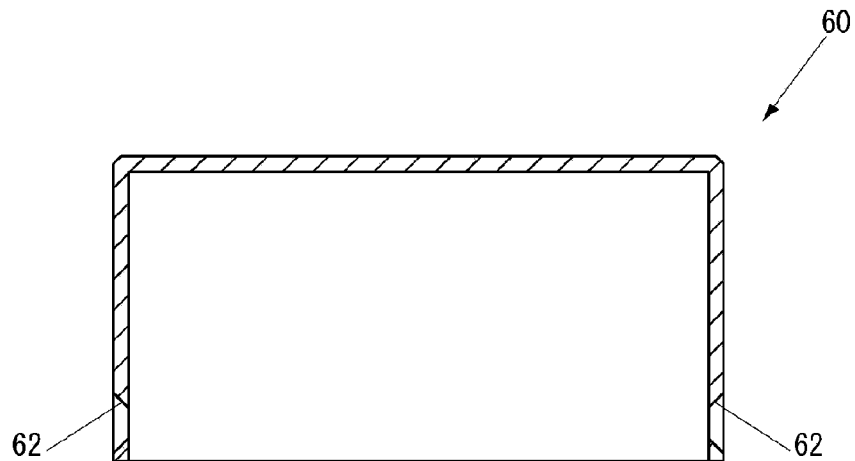


Fig. 11A

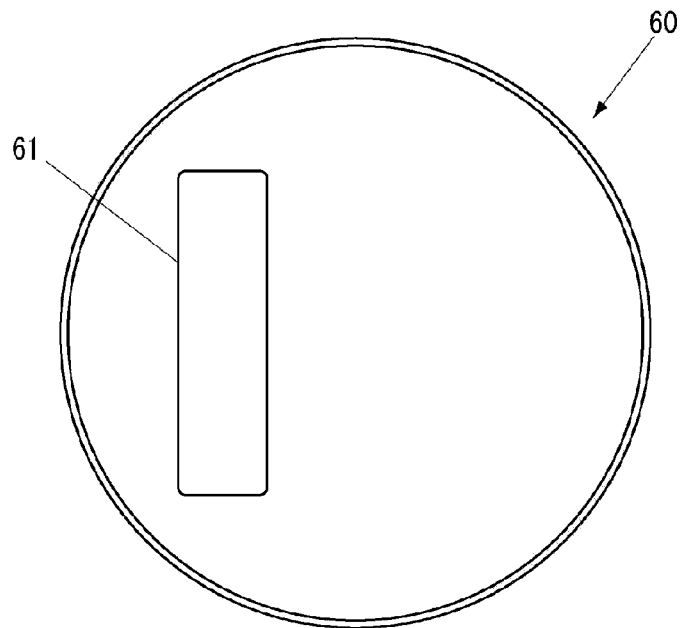
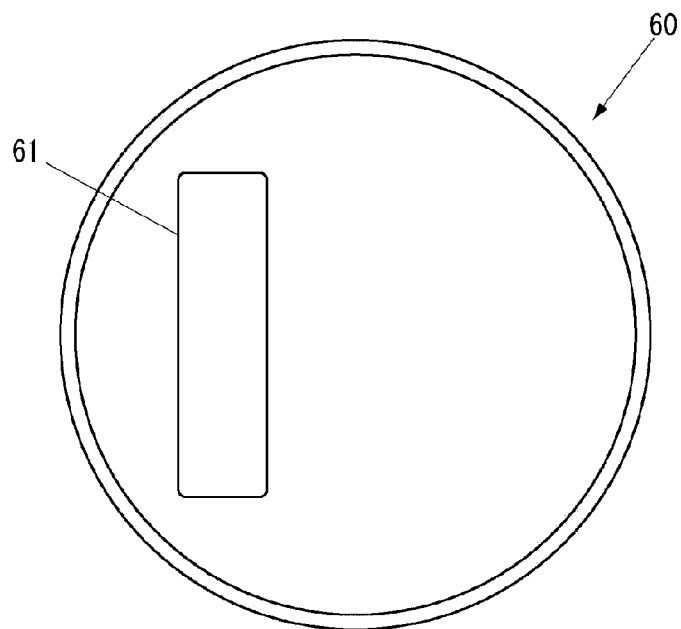


Fig. 11B



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LUBRICANT SENSOR**TECHNICAL FIELD**

The invention relates to a lubricant deterioration sensor for detecting deterioration of a machine lubricant.

BACKGROUND

As a lubricant deterioration sensor, an oil deterioration sensor in which an oil intrusion clearance for intrusion of a lubricant is formed on an optical path from an infrared LED (Light Emitting Diode) to a photodiode has been known. The oil deterioration sensor detects an amount of light which exits from the infrared LED and is absorbed by the lubricant in the oil intrusion clearance based on an amount of light received by the photodiode, and determines a degree of deterioration of the lubricant that correlates to the detected amount of absorbed light (see; for instance, Patent Documents 1 and 2).

However, the oil deterioration sensor described in Patent Documents 1 and 2 can detect a concentration of insoluble substance in the lubricant as a degree of deterioration of the lubricant but has a problem that types of contaminants in the lubricant can not be specified.

As a technique for specifying a type of contaminant in a lubricant, a technique in which a light is irradiated to a membrane filter by an LED after filtration of a lubricant is known. In the technique, a light reflected from contaminants on the membrane filter is converted by a light receiving element into RGB digital values, and types of the contaminants in the lubricant are specified according to the converted RGB digital values (see; for instance, Non-Patent Documents 1 and 2).

CITATION LIST**Patent Documents**

Patent Document 1: JP-A-7-146233

Patent Document 2: JP-A-10-104160

Non-Patent Document 1: Tomohiko YAMAGUCHI, four others, "Method for determining hues of contaminants in a lubricant," Engineering Department of Fukui University, Study Report March 2003, Vol. 51, No. 1, pp. 81 to 88.

Non-Patent Document 2: Tomonori HONDA, "Technique for diagnosing and inspecting deterioration of a lubricant," Academic Journal of Precision Engineering, 2009, Vo. 75, No. 3, pp. 359-362

SUMMARY OF INVENTION**Technical Problem**

However, in the techniques described in Non-Patent Documents 1 and 2, it is needed to sample a lubricant from a machine and to filter the sample by a membrane filter. Accordingly, the techniques have a problem that an instance is inferior.

Accordingly, an object of the present invention is to provide a lubricant deterioration sensor capable of instantly specifying types of contaminants in a lubricant of a machine.

Solution to Problem

A lubricant deterioration sensor to be mounted in a machine to detect deterioration of a lubricant of the machine according to the present invention is provided. The lubricant deterioration sensor includes:

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a white light emitting element for emanating white light;
a color light receiving element for detecting colors of received light;

a clearance forming member forming an oil clearance in which the lubricant enters; and

a support member supporting the white light emitting element, the color light receiving element, and the clearance forming member, wherein

the clearance forming member is transmissive so that the light emitted from the white light emitting element, and

the oil clearance is provided on an optical path from the white light emitting element to the color light receiving element.

By means of the configuration, the lubricant deterioration sensor of the invention detects colors from light of, among white light rays emitted from the white light emitting element, wavelengths that are not absorbed by contaminants in the lubricant at the oil clearance by use of the color light receiving element, so that colors of the contaminants in the lubricant of the machine can be instantly detected. In other words, the lubricant deterioration sensor of the invention can instantly specify, on the basis of the colors detected by the color light receiving element, types of contaminants in the lubricant of the machine.

In the lubricant deterioration sensor according to the present invention, a reflection surface for bending the optical path may be formed on the clearance forming member.

By means of the configuration, when compared with the configuration in which the optical path from the white light emitting element to the color light receiving element is straightforward, the entirety of the sensor of the invention can be miniaturized by placing the white light emitting element and the color light receiving element in close proximity to each other. Further, in the lubricant deterioration sensor of the invention, the clearance forming member plays the role of refracting the optical path as well as the role of forming the oil clearance. Hence, when compared with a configuration separately provided with a member for refracting the optical path instead of the clearance forming member, the number of parts can be curtailed.

In the lubricant deterioration sensor according to the present invention, the clearance forming member may have two rectangular prisms each of which has the reflection surface for bending the optical path at 90-degree angle, so that the optical path is bent at 180-degree angle by the reflection surfaces of the two rectangular prisms, and the oil clearance may be formed between the two rectangular prisms.

The configuration makes it possible to miniaturize the lubricant deterioration sensor of the invention by means of a simple configuration including a smaller number of parts.

The lubricant deterioration sensor according to the present invention may further include an optical path surrounding member for surrounding at least a portion of the optical path, wherein a surface of the optical path surrounding member is treated with antireflection processing.

By means of the configuration, the lubricant deterioration sensor of the invention prevents the color light receiving element from experiencing unwanted reflected light. Consequently, when compared with the configuration in which the color light receiving element experiences unwanted reflected light, the detection accuracy of colors of contaminants in the lubricant can be enhanced.

In the lubricant deterioration sensor according to the present invention, surfaces of the clearance forming member that form the oil clearance may be treated with a coating that prevents adhesion of stains in the lubricant, like sludge, or the

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clearance forming member may be made of a material that is resistant to adhesion of stains in the lubricant, like sludge.

By means of the configuration, the lubricant deterioration sensor of the invention can enhance accuracy of detection of colors of contaminants in the lubricant. Further, in the lubricant deterioration sensor of the invention, when the surfaces of the clearance forming member that form the oil clearance are given a coating that prevents adhesion of stains in the lubricant, like sludge, to the surfaces or when the clearance forming member is formed from a material that is less susceptible to adhesion of stains in the lubricant, like sludge, stains hardly adhere to the surfaces that form the oil clearance, so that a decrease in detection accuracy of colors of contaminants in the lubricant, which would otherwise be caused by adhesion of stains, can be prevented.

The lubricant deterioration sensor of the invention can instantly specify types of contaminants in the lubricant of the machine.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a front view of a lubricant deterioration sensor of one embodiment of the invention.

FIG. 2 is a front cross sectional view of the lubricant deterioration sensor shown in FIG. 1.

FIG. 3A it is a front view of a support member shown in FIG. 1, and FIG. 3B is a front cross sectional view of the support member shown in FIG. 1.

FIG. 4A it is a side view of the support member shown in FIG. 1, and FIG. 4B is a side cross sectional view of the support member shown in FIG. 1.

FIG. 5A is a plan view of the support member shown in FIG. 1, and FIG. 5B is a bottom view of the support member shown in FIG. 1.

FIG. 6A is a front view of a holder shown in FIG. 1, and FIG. 6B is a front cross sectional view of the holder shown in FIG. 1.

FIG. 7A is a side view of the holder shown in FIG. 1, and FIG. 7B is a side cross sectional view of the holder shown in FIG. 1.

FIG. 8A is a plan view of the holder shown in FIG. 1, and FIG. 8B is a bottom view of the holder shown in FIG. 1.

FIG. 9 is a view showing an optical path from a white LED to an RGB sensor shown in FIG. 2.

FIG. 10A is a front cross sectional view of a cover shown in FIG. 1, and FIG. 10B is a side cross sectional view of the cover shown in FIG. 1.

FIG. 11A is a plan view of the cover shown in FIG. 1, and FIG. 11B is a bottom view of the cover shown in FIG. 1.

DESCRIPTION OF EMBODIMENTS

An embodiment of the invention is hereunder described by reference to the drawings.

First, a configuration of a lubricant deterioration sensor of the embodiment is described.

FIG. 1 is a front view of a lubricant deterioration sensor 10 of the embodiment. FIG. 2 is a front cross sectional view of the lubricant deterioration sensor 10 mounted in a machine 90.

As shown in FIGS. 1 and 2, the lubricant deterioration sensor 10 is an apparatus for detecting deterioration of a lubricant 91 of the machine 90 mounted in the machine 90.

The lubricant deterioration sensor 10 includes a support member 20 that is made of an aluminum alloy for supporting respective parts of the lubricant deterioration sensor 10, a holder 30 that is secured to the support member 20 with a

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screw 11 and that is made of an aluminum alloy; a clearance forming member 40 that is retained by the holder 30, an electronic parts group 50 outfitted with a circuit board 51 that is secured to the support member 20 with screws 12, and a cover 60 that is secured to the support member 20 with a screw 13 and that is made of an aluminum alloy.

The clearance forming member 40 is made up of two rectangular glass prisms 41 and 42, and an oil clearance 40a that is a clearance for intrusion of the lubricant 91 is formed between the two rectangular prisms 41 and 42.

The electronic parts group 50 includes a white LED 52 mounted on the circuit board 51, an RGB sensor 53 mounted on the circuit board 51, a circuit board 54 placed opposite the white LED 52 and the RGB sensor 53 with reference to the circuit board 51, a plurality of columns 55 for anchoring the circuit board 51 and the circuit board 54, and the circuit board 56 placed opposite the circuit board 51 with reference to the circuit board 54, a plurality of columns 57 for securing the circuit board 54 and the circuit board 56; and a connector 58 mounted opposite the circuit board 54 with reference to the circuit board 56. A plurality of electronic parts are mounted on the circuit board 51, the circuit board 54, and the circuit board 56. Further, the circuit board 51, the circuit board 54, and the circuit board 56 are electrically connected to each other.

The lubricant deterioration sensor 10 is equipped with an O ring 14 for preventing leakage of the lubricant 91 from a clearance between the support member 20 and the machine 90 and an O ring 15 for preventing leakage of the lubricant 91 from a clearance between the support member 20 and the holder 30.

FIG. 3A is a front view of the support member 20. FIG. 3B is a front cross sectional view of the support member 20. FIG. 4A is a side view of the support member 20. FIG. 4B is a side cross sectional view of the support member 20. FIG. 5A is a plan view of the support member 20. FIG. 5B is a bottom view of the support member 20.

As shown in FIGS. 1 to 5B, the support member 20 includes a screw section 21 secured to a tapped hole 90a of the machine 90, a hexagonal tool contact 22 that is to be gripped with a tool when the screw section 21 is rotated with respect to the tapped hole 90a of the machine 90, and a holder housing section 23 for housing the holder 30. Moreover, the support member 20 are formed with a hole 24 for insertion of the white LED 52, a hole 25 for insertion of the RGB sensor 53, two holes 26 for insertion of the screw 11, two tapped holes 27 for insertion of the screws 12, and two tapped holes 28 for insertion of the screw 13.

The support member 20 supports the white LED 52 and the RGB sensor 53 by way of the circuit board 51. The support member 20 supports the clearance forming member 40 by way of the holder 30.

FIG. 6A is a front view of the holder 30. FIG. 6B is a front cross sectional view of the holder 30. FIG. 7A is a side view of the holder 30. FIG. 7B is a side cross sectional view of the holder 30. FIG. 8A is a plan view of the holder 30. FIG. 8B is a bottom view of the holder 30. FIG. 9 is a view showing an optical path 10a from the white LED 52 to the RGB sensor 53.

As shown in FIGS. 1 and 2 and FIGS. 6A to 9, the holder 30 includes a prism housing 31 that houses the rectangular prism 41, a prism housing 32 that houses the rectangular prism 42, and an LED housing 33 that houses the white LED 52. the holder 30 are formed with a hole 34 for the RGB sensor 53, a hole 35 that establishes mutual communication between the prism housing 31 and the LED housing 33, a hole 36 that establishes mutual communication between the prism housing 32 and the hole 34, two tapped holes 37 for screw-engagement

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ment of the screw 11, a groove 38 to which the O ring 15 fits, an annular groove 39a for preventing an adhesive which fixes the rectangular prism 41 to the prism housing 31 from entering the hole 35, and an annular groove 39b for preventing an adhesive which fixes the rectangular prism 42 to the prism housing 32 from entering the hole 36.

The prism housing 31 includes two walls 31a between which the rectangular prism 41 is to be inserted. The walls 31a fix the rectangular prism 41 by means of an adhesive. The prism housing 32 includes two walls 32a between which the rectangular prism 42 is to be inserted. The walls 32a fix the rectangular prism 42 by means of an adhesive.

The holder 30 surrounds at least a portion of the optical path 10a from the white LED 52 to the RGB sensor 53 by means of the LED housing 33, the hole 35, the prism housing 31, the prism housing 32, the hole 36, the hole 34, making up an optical path surrounding member of the invention.

A surface of the holder 30 is treated by antireflection; for instance, mat black anodized aluminum treatment.

As shown in FIG. 9, the oil clearance 40a of the clearance forming member 40 is placed on the optical path 10a from the white LED 52 to the RGB sensor 53.

The rectangular prisms 41 and 42 are transmissive so that light emitted from the white LED 52 transmits therethrough. The rectangular prism 41 has an incident surface 41a on which light emitted by the white LED 52 falls, a reflection surface 41b that reflects the light fell on the incident surface 41a, to thus make a 90-degree turn of a traveling direction of light, and an exit surface 41c from which the light reflected by the reflection surface 41b exits. The rectangular prism 42 has an incident surface 42a on which light exited from the exit surface 41c of the rectangular prism 41 falls, a reflection surface 42b that reflects the light fell on the incident surface 42a, to thus make a 90-degree turn of a traveling direction of light, and an exit surface 42c from which the light reflected by the reflection surface 42b exits.

The incident surface 41a, the reflection surface 41b, and the exit surface 41c of the rectangular prism 41, and the incident surface 42a, the reflection surface 42b, and the exit surface 42c of the rectangular prism 42 are optically polished. The reflection surface 41b of the rectangular prism 41 and the reflection surface 42b of the rectangular prism 42 each are covered with an aluminum evaporated film. In order to protect the aluminum evaporated film that has a low degree of hardness and adhesion, the aluminum evaporated film is further coated with an SiO₂ film.

The optical path 10a is bent at 90-degree angle on the reflection surface 41b of the rectangular prism 41, further is bent at 90-degree angle also on the reflection surface 42b of the rectangular prism 42. To be specific, the optical path 10a is bent at 180 degrees angle by the clearance forming member 40.

A distance between the exit surface 41c of the rectangular prism 41 and the incident surface 42a of the rectangular prism 42 is a length of the oil clearance 40a. The length of the oil clearance 40a is 1 millimeter for instance. When the length of the oil clearance 40a is too short, contaminants in the lubricant 91 become difficult to flow through the oil clearance 40a appropriately, so that a degree of detection accuracy of a color of the contaminants in the lubricant 91 deteriorates. In the meantime, when the length of the oil clearance 40a is too long, light emitted from the white LED 52 is too absorbed by the contaminants in the lubricant 91 in the oil clearance 40a to reach the RGB sensor 53, so that the degree of detection accuracy of the color of the contaminants in the lubricant 91 also deteriorates. Consequently, it is preferable that the length

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of the oil clearance 40a be appropriately set such that the degree of detection accuracy of the color of the contaminants in the lubricant 91 improves.

The white LED 52 is an electronic part that emits white light and makes up a light emitting element of the invention. For instance, NSPW500GS-K1 manufactured by Nichia Corporation, can be used as the white LED 52.

The RGB sensor 53 is an electronic part that detects a color of received light and makes up a color light receiving element of the invention. For instance, S9032-02 manufactured by Hamamatsu Photonics K.K. can be used as the RGB sensor 53.

As shown in FIG. 2, the connector 58 is connected to a connector 59 of an external device of the lubricant deterioration sensor 139a and is fed with electric power from the external device by way of a connector 95. A detection result of the lubricant deterioration sensor 10 is output to the external device as an electric signal by way of the connector 95.

FIG. 10A is a front cross sectional view of the cover 60. FIG. 10B is a side cross sectional view of the cover 60. FIG. 11A is a plan view of the cover 60. FIG. 11B is a bottom view of the cover 60.

As shown in FIGS. 1, 2, 10A to 11B, the cover 60 has a hole 61 for insertion of the connector 58 and two holes 62 for insertion of the screw 13.

A surface of the cover 60 is treated by antireflection; for instance, mat black anodized aluminum treatment.

Next, a method for assembling the lubricant deterioration sensor 10 is described.

First, an adhesive is applied to two surfaces of the surfaces of the rectangular prism 41 that contact the two walls 31a of the prism housing 31 as well as to an outer peripheral surface of the groove 39a that contacts the incident surface 41a of the rectangular prism 41 of the prism housing 31 of the holder 30, whereby the rectangular prism 41 is secured to the prism housing 31 by means of the adhesive. In addition, an adhesive is applied to two surfaces of the surfaces of the rectangular prism 42 that contact the two walls 32a of the prism housing 32 as well as to an outer peripheral surface of the groove 39b which contacts the exit surface 42c of the rectangular prism 42 of the prism housing 32 of the holder 30, whereby the rectangular prism 42 is secured to the prism housing 32 by means of the adhesive. Further, the white LED 52 is secured to the LED housing 33 of the holder 30 by means of the adhesive.

Next, the holder 30 outfitted with the O ring 15 is secured, by means of the screw 11, to the holder housing 23 of the support member 20 outfitted with the O ring 14.

The electronic parts group 50 into which various electronic parts except the white LED 52; namely, the circuit board 51, the RGB sensor 53, and the connector 58, are previously assembled is secured to the support member 20 by the screws 12, thereby the white LED 52 is soldered to the circuit board 51.

Finally, the cover 60 is secured to the support member 20 by the screw 13.

A method for mounting the lubricant deterioration sensor 10 to the machine 90 is now described.

First, the tool contact 22 of the support member 20 is pinched with a tool, and the screw 21 of the support member 20 is screwed into the tapped hole 90a of the machine 90, whereby the lubricant deterioration sensor 10 is secured to the machine 90.

The connector 95 of an external device of the lubricant deterioration sensor 10 is connected to the connector 58.

Next, operation of the lubricant deterioration sensor 10 is described.

In the lubricant deterioration sensor **10**, white light is emitted from the white LED **52** by means of the electric power fed from an external device by way of the connector **58**.

The lubricant deterioration sensor **10** outputs amounts of RGB colors of light received by the RGB sensor **53** as an electric signal to an external device by way of the connector **58**.

The lubricant deterioration sensor **10** can also be separately equipped with a sensor other than the RGB sensor **53**. For instance, when a temperature sensor for detecting a temperature of the lubricant **91** is included in the electronic parts group **50**, the lubricant deterioration sensor **10** can output a temperature detected by the temperature sensor to an external device as an electric signal by way of the connector **58**.

As described above, the lubricant deterioration sensor **10** detects colors from light of, among white light rays emitted from the white LED **52**, wavelengths that are not absorbed by contaminants in the lubricant **91** in the oil clearance **40a** by use of the RGB sensor **53**, so that colors of the contaminants in the lubricant **91** of the machine **90** can be instantly detected. In other words, the lubricant deterioration sensor can instantly specify, on the basis of the colors detected by the RGB sensor **53**, types and amounts of contaminants in the lubricant **91** of the machine **90** by use of an external device, like a computer. Incidentally, the lubricant deterioration sensor **10**, electronic parts that specify types and amounts of contaminants in the lubricant **91** of the machine **90** from the colors detected by the RGB sensor **53** can also be included in the electronic parts group **50**.

In the lubricant deterioration sensor **10**, the reflection surfaces **41b** and **42b** for refracting the optical path **10a** are formed on the clearance forming member **40**. Therefore, when compared with the configuration in which the optical path **10a** from the white LED **52** to the RGB sensor **53** is straightforward, the entirety of the sensor can be miniaturized by placing the white LED **52** and the RGB sensor **53** in close proximity to each other. Further, in the lubricant deterioration sensor **10**, the clearance forming member **40** plays the role of bending the optical path **10a** as well as the role of forming the oil clearance **40a**. Hence, when compared with a configuration separately provided with a member for refracting the optical path **10a** instead of the clearance forming member **40**, the number of parts can be curtailed.

In particular, in the lubricant deterioration sensor **10**, the clearance forming member **40** is made up of the two rectangular prisms **41** and **42** on which there are formed the reflection surfaces **41b** and **42b** for effecting 90-degree refraction of the optical path **10a**. The optical path **10a** is subjected to 180-degree refraction by means of the reflection surfaces **41b** and **42b** of the two rectangular prisms **41** and **42**, and the oil clearance **40a** is formed between the two rectangular prisms **41** and **42**. Hence, the lubricant deterioration sensor can be miniaturized by means of a simple configuration that includes a smaller number of parts.

Further, the lubricant deterioration sensor **10** is equipped with the holder **30** that surrounds at least a portion of the optical path **10a**. The surface of the holder **30** is treated with antireflection processing. Hence, the RGB sensor **53** can be prevented from experiencing unwanted reflected light. Consequently, when compared with the configuration in which the RGB sensor **53** experiences unwanted reflected light, the lubricant deterioration sensor **10** can enhance the detection accuracy of colors of contaminants in the lubricant **91**.

In the lubricant deterioration sensor **10**, the surfaces of the clearance forming member **40** that form the oil clearance **40a**; namely, the exit surface **41c** of the rectangular prism **41** and the incident surface **42a** of the rectangular prism **42**, can also

be treated with oil repellent treatment. In the lubricant deterioration sensor **10**, when the exit surface **41c** of the rectangular prism **41** and the incident surface **42a** of the rectangular prism **42** are given oil repellent treatment, the exit surface **41c** of the rectangular prism **31** and the incident surface **42a** of the rectangular prism **42** are less susceptible to stains. Therefore a decrease in detection accuracy of colors of contaminants in the lubricant **91**, which would otherwise be caused by stains, can be prevented.

In the lubricant deterioration sensor **10**, the layout of the white LED **52** and the RGB sensor **53** may also be different from that described in the embodiment. For instance, in the lubricant deterioration sensor **10**, the optical path **10a** from the white LED **52** to the RGB sensor **53** may also be straightforward.

In the lubricant deterioration sensor **10**, the optical path **10a** can also be bended by means of a configuration other than the rectangular prism.

For instance, fluorine coating, a transparent silicone resin, and the like, are available as coating that makes it difficult for stains (sludge) in a lubricant to adhere.

The patent application is based on Japanese Patent Application JP-2010-269097 (filed on Dec. 2, 2010), the subject matter of which is incorporated herein by reference in its entirety.

INDUSTRIAL APPLICABILITY

The lubricant deterioration sensor of the invention enables instant specification of types of contaminants in a lubricant of a machine

REFERENCE SIGNS LIST

10 LUBRICANT DETERIORATION SENSOR
10a OPTICAL PATH
20 SUPPORT MEMBER
30 HOLDER (OPTICAL PATH SURROUNDING MEMBER)
40 CLEARANCE FORMING MEMBER
40a OIL CLEARANCE
41 RECTANGULAR PRISM
41b REFLECTION SURFACE
41c EXIT SURFACE (SURFACE THAT MAKES UP OIL CLEARANCE)
42 RECTANGULAR PRISM
42a ENTRANCE SURFACE (SURFACE THAT MAKES UP CLEARANCE)
42b REFLECTION SURFACE
52 WHITE LED (LIGHT EMITTING ELEMENT)
53 RGB SENSOR (COLOR RECEIVING ELEMENT)
90 MACHINE
91 LUBRICANT

The invention claimed is:

1. A lubricant sensor, comprising:
 - a white light emitting element configured to emit light;
 - a color light receiving element, arranged with the white light emitting element side by side, and configured to detect color of the light;
 - a clearance forming member forming an oil clearance in which a lubricant enters;
 - a support member supporting the white light emitting element, the color light receiving element and the clearance forming member; and
 - an optical path surrounding member,

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wherein the clearance forming member is transmissive so that the light emitted from the white light emitting element transmits therethrough,
 the oil clearance is provided on an optical path from the white light emitting element to the color light receiving element, and
 the optical path surrounding member surrounds at least a part of the optical path.
 2. The lubricant sensor according to claim 1, wherein a space on the optical path between the white light emitting element and the clearance forming member is formed by a hole.
 3. The lubricant sensor according to claim 1, wherein the clearance forming member includes two rectangular prisms each of which has a reflection surface for bending the optical path,
 each of the rectangular prisms has an apex angle which is defined by two surfaces therebetween and is orthogonal, and a hypotenuse surface opposing the apex angle,
 the reflection surface is formed on the hypotenuse surface of each of the rectangular prisms, and
 the oil clearance is formed between one of the two surfaces defining the apex angle of one of the rectangular prisms and one of the two surfaces defining the apex angle of the other one of the rectangular prisms.

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4. The lubricant sensor according to claim 1, further comprising
 a screw portion configured to fix the optical sensor to a mating member,
 wherein the optical path surrounding member is disposed inside of the screw portion.
 5. The lubricant sensor according to claim 1, wherein a width of a space on the optical path between the white light emitting element and the clearance forming member at a side of the clearance forming member is shorter than a width of the space at a side of the white light emitting element, and
 the optical path between the white light emitting element and the clearance forming member and the optical path between the color light receiving element and the clearance forming member extend in a direction in which the optical sensor is inserted to a mating member.
 6. The lubricant sensor according to claim 1, wherein a groove surrounding an opening of a space on the optical path between the white light emitting element and the clearance forming member is formed on a surface of the supporting member to which the clearance forming member is attached.

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